(12) UK Patent Application (19) GB (11) 2 008 646 A

(21) Application No 7841844
(22) Date of filing 25 Oct 1978
(23) Claims Filed 25 Oct 1978
(30) Priority data
(31) 31254/77
(32) 26 Jul 1977
(33) United Kingdom (GB)
(43) Application published 6 Jun 1979
(51) INT CL²
E04B 1/345
(52) Domestic classification
E1A 716 750 752
F4U 60
(56) Documents cited
GB 1526062
GB 1525926
GB 1516514
GB 1506576
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GB 1495709
GB 1446493
GB 1272657
GB 1145060
(58) Field of search
C6F
E1A
E1R
E1W
F4U
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(54) Modifying Thermal Properties of Membranous Double Wall Constructions

(57) A method of regulating the properties of radiation reflection, transmission and/or absorption of a double membrane structural unit, having inner and outer membranes, comprises adjusting the direction of flow and/or nature of a fluid flowing between the membranes and/or adjusting the spacing between the membranes. Such a method is conveniently used in connection with a building structure, such as a swimming pool, incorporating one or more such double membrane structural units, and enables regulation of the atmospheric conditions within the structure. The fluid between the membranes may circulate by forced or gravity flow and be a gas, smoke or coloured liquid a suspension of absorbing particles in liquid. The fluid may transfer heat to or from a water or rock heat stove and may heat or cool the interior of the construction. the inner membrane may be black or reflective and the construction supported by pressurised air or a framework.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig. 1.

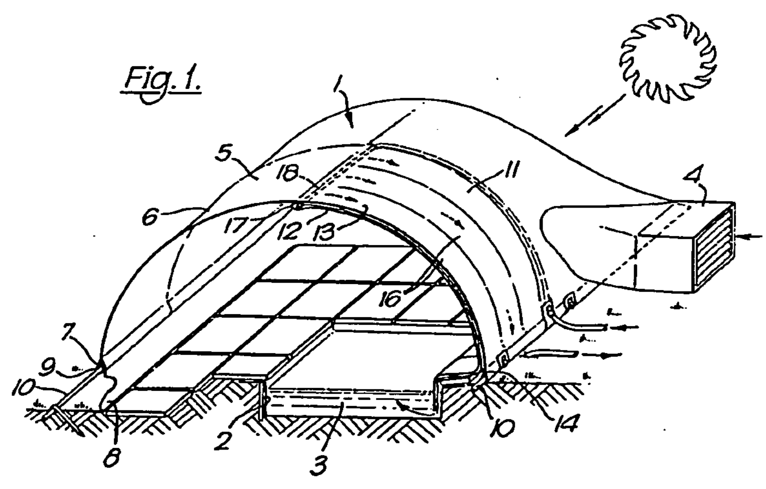

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Fig.1.

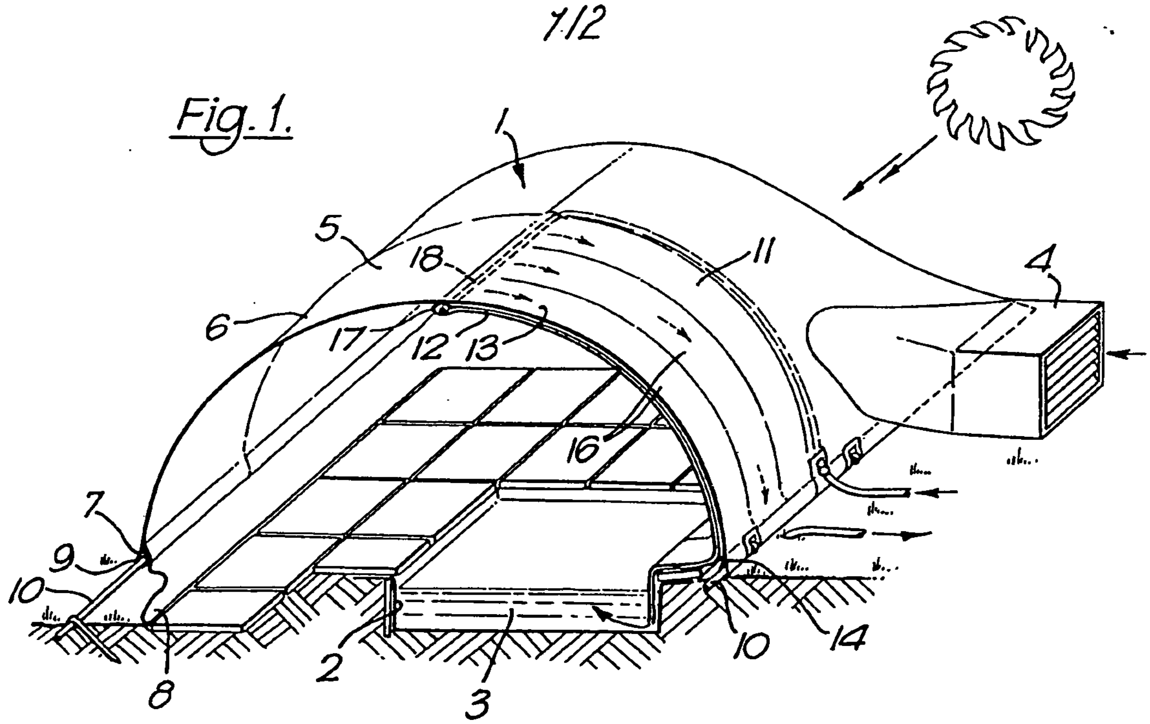


Fig.2.

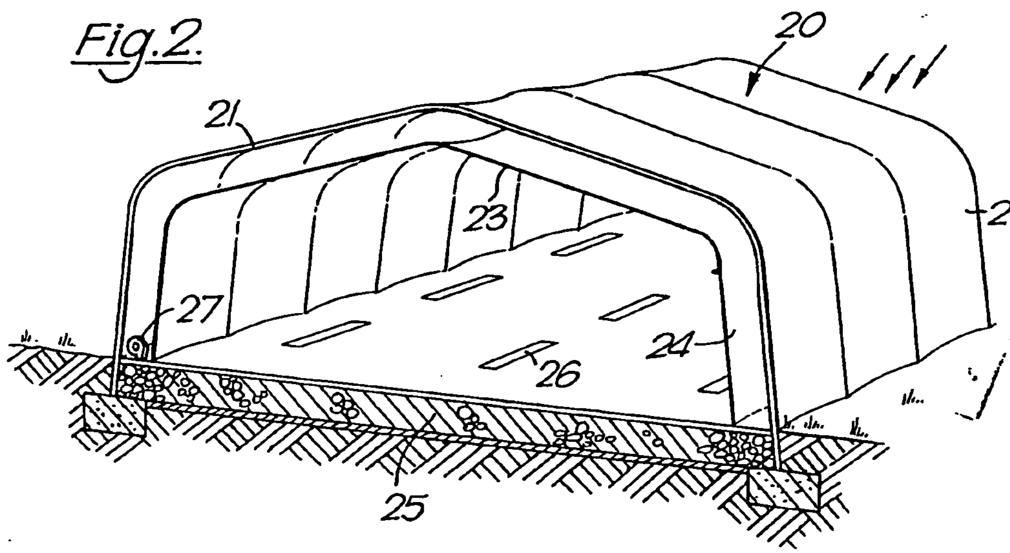
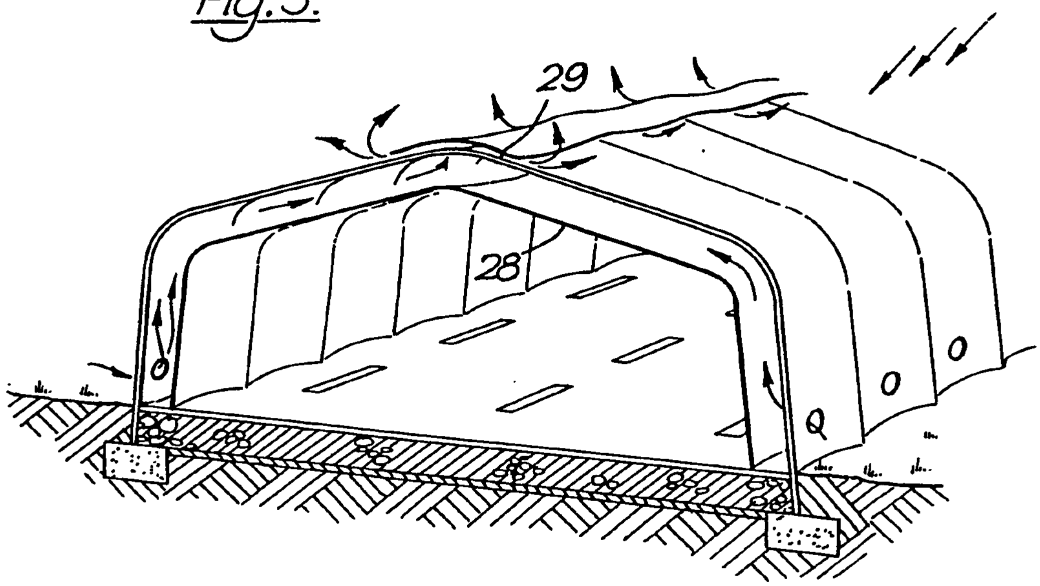


Fig. 3.



SPECIFICATION
Improvements In or Relating to Structural Units

This invention relates to structural units of double wall construction, comprising inner and outer membranes of suitable material, and concerns particularly, but not exclusively, the regulation of the properties of radiation reflection, transmission and/or absorption of such a structural unit.

According to one aspect of the present invention there is provided a method of adjusting the properties of radiation reflection, transmission and/or absorption of a structural unit of double wall construction , having inner and outer membranes, which method comprises adjusting the direction of flow and/or nature of a fluid flowing between the membranes and/or adjusting the spacing between the membranes.

The properties of radiation reflection, transmission and/or absorption of such a structural unit depend to a certain extent on the constructional details of the unit, and hence by adjusting the constructional details and also the variables mentioned above it is possible to produce desired properties and behaviour of such a unit.

For example, consider a double wall structural unit having on outer membrane that is at least substantially transparent to short wave solar radiation and relatively opaque to long wave heat radiation, such a membrane conveniently has been made of, for example, a transparent plastics film material such as PVC, polyester or polyethelene, and the inner membrane being absorbent with respect to solar radiation, for example being formed of black or blacked plastics film material. If a liquid, for example water or a specially prepared highly absorptive liquid such as, for example, Solvap Green, Eosin, soluble cutting oil or an aqueous solution of carbon black is fed to flow over the surface of the inner membrane withitn the inter-membrane space, the behaviour of the unit depends, among other factors, upon the surrounding conditions.

Thus, when the outer membrane of the structural unit is exposed to a source of solar radiation, for example by being oriented to receive rays from the sun, such radiation passes through the outer transparent membrane and is absorbed by the inner membrane and the liquid flowing thereover, the inner membrane and liquid thus becoming heated. Liquid heated in this manner may conveniently be passed to heat storage means, the heated liquid either being stored in tanks or the heat thereof being transferred to other storage media such as an oil or a rock heat store. Alternatively, the thus heated liquid may be used directly for providing a heated volume of water for use in, for example, such activities as swimming, the rearing of fish, algae or plants, or in industrial processes. Further, with such an arrangement, some of the absorbed heat will be re-radiated from the inner membrane to the side of the structural unit remote from the source of solar radiation, for example the interior of a structure incorporating such a unit, thus heating air in that region.

In contrast, if the outer membrane of such a unit is not exposed to a source of radiation, for example at night, any heat absorbed by the inner membrane, and possibly also heat within a structure incorporating the unit, will be re-radiated, passing through the outer membrane to the surrounding air.

The properties and behaviour of such a unit can be modified by adjusting the spacing between the inner and outer membranes. For example, if the inner and outer membranes are so spaced that the outer membrane contacts the surface of the flowing liquid, an even surface will be induced to the surface of the flowing liquid, thus increasing the absorptive properties thereof. Further, when such an arrangement is not exposed to a source of solar radiation, for example at night, the re-radiation of any absorbed heat is enhanced by the elimination of an intervening insulating mass of air, and such an arrangement may therefore conveniently be used to effect cooling, at night, of the interior of a building structure incorporating such a unit.

Alternatively, if the membranes are so spaced apart that there is an air gap between the upper surface of the flowing liquid and the upper membrane, some evaporation of the flowing liquid may occur, especially if the outer membrane is exposed to a source of solar radiation, resulting in the deposition of a thin layer of condensation droplets on the underside of the outer membrane. The condensation droplets form a highly reflective layer that prevents the ingress of solar radiation and may thus be used to prevent the transmission of radiation through the structural unit, for example preventing the rise of, or possible even lowering, the temperature within a structure incorporating such a unit upon exposure to solar radiation. Such a unit may thus be used as, for example, an aid to air conditioning within a structure incorporating the unit. With such an arrangement, evaporation of the liquid may be promoted by passing a saturated vapour between the membranes.

The spacing between the membranes of such a structural unit may be adjusted in a variety of manners, one convenient manner involving adjusting the gas pressure in the inter-membrane space, an increase of pressure causing an increase of spacing and a reduction of pressure causing a reduction of spacing.

In a further arrangement, a gas, for example air smoke or water vapour, may be passed between the membranes of such a unit instead of, or as well as, a liquid. With such an arrangement, the gas behaves in a similar manner to a liquid, as discussed above, becoming heated when the outer membrane is exposed to a source of solar radiation, some heat being re-radiated through the inner membrane, for example to the interior of a structure incorporating such a unit. The heated

gas may conveniently be fed to a heat store such as, for example, a rock or water heat store, from which heat can be withdrawn as desired for use in, for example, heating the interior of a structure incorporating such a unit. Furthermore, by reversing the direction of flow of the gas so that it flows from the heat store to the inter-membrane space, heat may be withdrawn from the store and reradiated to the atmosphere through the outer membrane of the structural unit, the unit thus functioning in a cooling capacity. The flow of gas in such an arrangement may conveniently be caused by means of a suitable fan arrangement that is preferably reversible to permit reversal of the flow of gas, as discussed above.

In yet a further alternative arrangement the inner membrane of a double wall structural unit may be of a material that is at least partly reflective to solar radiation, such a membrane conveniently being made of, for example, a plastic film material that is "silvered", for example by metal deposition on the film or by the incorporation of a suitable metallic layer in a laminated skin construction. With a structural unit of such a construction the amount of solar radiation that can be transmitted there through is considerably reduced, thus reducing the possible heating effect of solar radiation incident upon the outer membrane upon air on the side of the unit remote from the source of solar radiation, for example the interior of a building structure incorporating such a unit. Furthermore, by causing the flow of gas through the inter-membrane space from a heat stores, for example a rock a water heat store, by means of, for example, natural convection, possibly assisted by the use of a suitable fan, to a suitable vent, an additional cooling effect may be provided.

In a further aspect, the present invention provides a structural unit of double wall construction, comprising an inner membrane, an outer membrane, means for causing the flow of a fluid between the membranes, and means for adjusting the direction of flow and/or the nature of the fluid and/or adjusting the spacing between the membranes.

The above discussed method and structural units of the invention find convenient application in connection with various building structures and, in particular, in the regulation of atmospheric conditions within the building structures.

For example, a building structure may conveniently comprise of one or more structrual units in accordance with the present invention, the units forming either the whole of the wall portions of a building structure or only part thereof, possibly only that part of a fixed structure that is usually oriented towards the sun. Particularly convenient applications include those where it is desirable to provide a heated volume of fluid, such as water, for example for use in such activities as swimming, the rearing of fish, algae or plants, the building structure thus performing the dual function of protecting the volume of fluid and also providing a source of heated fluid. For example, a structural unit in accordance with the present invention may conveniently comprise or be incorporated in a swimming pool cover.

Hence, in a further aspect the present invention provides a building structure comprising a structural unit in accordance with the present invention.

Such a building structure may conveniently be supported upon a rigid, e.g. metal, frame, such as a conventional building frame. Alternatively, such a building structure may be an air structure, that is to say a structure that is supported by the application of a pressure differential to the boundary walls thereof, usually by substantially sealing the structure and continually supplying air under pressure to the interior thereof to maintain a superatmospheric pressure therein.

By adjusting, in the manners discussed above, the properties of a structrual unit forming or incorporated in a building structure, the atmospheric conditions within the structure may be regulated to a certain extent.

Hence, in yet a further aspect the present invention provides a method of regulating atmospheric conditions within a building structure comprising a structural unit in accordance with the present invention, which method comprises adjusting the direction of flow and/or the nature of a fluid flowing between the membranes and/or adjusting the spacing between the membranes.

Preferred embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic part-sectional perspective view of an air structure in accordance with the present invention;

Figure 2 is a schematic part-sectional perspective view of a building structure in accordance with the present invention and supported upon a metal frame;

Figure 3 is a schematic part-sectional perspective view of an alternative building structure in accordance with the present invention and supported upon a metal frame.

Referring to the drawings, Figure 1 illustrates an air structure 1 that is for the most part of conventional construction and that is illustrated as being used as a cover for a pool 2 containing a volume of liquid, e.g. water, 3 that may be used for such purposes as swimming or fish or algae farming.

As is usual with air structures, the periphery of the structure 1 is sealed to the ground, as will be described below, the structure thus defining a substantially sealed enclosure. The wall portions of the structure 1 are of flexible material that is substantially impermeable to air and that may be stiffened and supported in the configuration shown in Figure 1 by the application of a pressure differential thereto by continually supplying air under pressure to the interior of the structure by means of a conventional fan arrangement 4 to maintain a superatmospheric pressure within the structure 1. When inflated in this manner, the

structure 1 adopts a generally tunnel-like configuration, as shown in Figure 1, having a semi-cylindrical middle section 5 and rounded off, part-spherical end sections.

The greater part of the wall portions of the structure 1, including the left-hand portion as viewed in Figure 1, is of single wall construction, comprising a single membrane 6 of any suitable material, for example those conventionally used in air structure construction, such as PVC coated fabric or a film of a plastics material such as PVC, polyethylene or polyester. The lower portion of such single membrane wall portions is bifurcated, being divided into an outer membrane portion 7 and an inner membrane portion 8. The outer membrane portion 7 is folded over to form a tunnel-like housing 9 at the base of the structure 1 into which is threaded an anchorage cable 10 arranged to provide a sealing connection between the periphery of the structure 1 and the surface upon which it is supported. The inner membrane portion 8 is extended to form a skirt region that passes over the ground within the interior of the structure 1, assisting sealing.

The right-hand portion of the structure 1, as viewed in Figure 1, further includes a wall region 11 that is of double wall construction, comprising an inner membrane 12 and an outer membrane 13. The inner membrane 12 is highly absorptive with respect to solar radiation and is effective to convert such radiation into heat energy, conveniently being formed of a black or blackened plastics sheet material such as PVC, polyester or polyethylene. In contrast, the outer membrane 13 is of a material that is at least substantially transparent to solar radiation and conveniently comprises a sheet of a transparent plastics material, such as those mentioned above.

The lower portion of the outer membrane 13 is folded to form a tunnel-like housing 14 that is similar to housing 9 and arranged to receive anchorage cable 10 for sealing the structure 1 to the ground. The lower portion of the inner membrane 12 is extended to form a skirt portion 15 passing into the liquid 3 contained within the pool 2.

The inner and outer membranes 12 and 13 are linked together at intervals, for example by stitching or welding, so as to define a series of elongate channels 16 extending perpendicularly to the axis of the curvature of the central portion 5. The inner and outer membranes are not, however, linked together in this manner adjacent the upper end portions thereon, the membranes thus defining a further tunnel-like housing 17 extending substantially parallel to the axis of curvature of the middle section 5 at the uppermost part of the structure.

The structure 1 is provided with a liquid circulation system arranged to cause the flow of a liquid, such as those discussed above, between the membranes 12 and 13. The circulation system thus comprises an apertured distribution pipe 18 running along the length of housing 17 between the inner and outer membranes. Liquid passing through the pipe 17 will thus pass through the apertures therein and flow between the membranes and down over the inner membrane 12 in the direction of the arrows, being diverted at the base of the structure to flow into the volume of liquid 3 within the pool 2.

An outlet pipe 19 is provided extending from within the pool 2 to a pump (not shown) that in turn communicates with an inlet pipe 20 arranged to supply the liquid to the distribution pipe 18. Liquid may thus be continuously circulated by means of the pump from the pool 2 to the inter-membrane space.

Access to the interior of the structure 1 is provided by any suitable access system (not shown) such as those conventionally used with air structures, for example a conventional airlock door.

It will be apparent that when the double membrane wall region 11 of the structure 1 is exposed to solar radiation, such radiation will pass through the transparent outer membrane 13 and be absorbed by the absorptive inner membrane 12 and liquid flowing thereover, thus causing the inner membrane 12 and liquid to become heated, the double membrane region thus functioning as a liquid heater effective to heat liquid passing to the pool.

It will further be apparent that the properties of the double membrane wall region 11 can be modified as discussed above to produce properties to suited to particular circumstances and conditions.

For example, if the spacing between the inner and outer membranes 12 and 13 is increased, a degree of evaporation of the liquid may occur causing a thin layer of condensation droplets to be deposited on the under side of the outer transparent membrane 13, forming a highly reflective layer that will prevent solar radiation from being absorbed by the absorptive inner membrane 12 and the liquid.

Such membrane spacing adjustment may conveniently be effected by varying the air pressure within the air structure 1, thus causing a corresponding variation in the tension of the inner membrane 12. For example, if the internal pressure is lowered portions of the inner membrane 12 will be caused to move in a downwards direction under the action of the weight of the liquid and/or pressure of gas between the inner and outer membranes, thus causing an increase in the distance between the inner and outer membranes. Similarly, if the internal pressure is increased, the spacing between the inner and outer membranes will be reduced.

It will also be apparent that a swimming pool cover or other similar structure could also be supported upon a conventional rigid, e.g. metal, frame structure, and need not necessarily be an air structure.

Referring now to Figure 2, there is illustrated an alternative arrangement comprising a double membrane building structure 20 supported upon

a standard rigid, e.g. metal, frame 21. Structure 20 comprises an outer transparent membrane 22 and an inner absorptive membrane 23, the membranes being of any suitable materials such as those discussed priviously. The inter-membrane space 24 communicates with an underground heat store 25, conveniently a rock or water heat store, that communicates with the interior of the building via a plurality of adjustable air vents 26. One or more fans 27 are provided at suitable locations, if desired, for promoting the flow to gas, for example air, through the inter-membrane space 2.

When the illustrated building structure 20 is exposed to solar radiation, such radiation passes through the transparent outer membrane 22 and is absorbed by the absorptive inner membrane 23 and gas within the inter-membrane space 24, the radiation being converted into heat energy. By causing the gas to circulate in such a direction as to pass from the inter-membrane space 24 to the underground heat store 25, using the fans 27 if necessary, the heat will be transferred to the heat store 25 and can be admitted into the interior of the building via vents 26, as desired.

By causing the gas to flow in the reverse direction, from the heat store 25 to the inter-membrane space 24, heat can be withdrawn from the heat store and passed in the circulating gas to the ambient atmosphere via a suitable vent (not shown).

The illustrated structure can thus be used both for heating and cooling purposes.

Referring now to Figure 3, a further alternative arrangement is shown that resembles the structure illustrated in Figure 2 in many respects, but differs therefrom in having an inner membrane 28 that is reflective with respect to solar radiation. Such construction consequently prevents or reduces the possibility of solar radiation passing through the double membrane wall of the structure to the interior thereof. Furthermore, by arranging for aid to flow upwardly from the heat store, in the direction indicated by the arrows, either by convection due to heat within the store, or assisted by means of fans or blowers, heat may be withdrawn from the heat store and expelled to the atmosphere via a ventilation arrangement 29 running along the length of the structure at the top thereof, thus having a cooling effect.

It will be apparent that the properties of the structures illustrated in Figures 2 and 3 can be modified by adjusting the nature of the fluid flowing between the membranes. For example, if a saturated vapour, for example saturated water vapour, is added to the gas flowing therethrough, condensation droplets will form upon the outer membrane, modifying the properties as discussed above.

Claims

1. A method of adjusting the properties of radiation reflection, transmission and/or absorption of a structural unit of double wall construction, having inner and outer membranes, which method comprises adjusting the direction of flow and/or nature of a fluid flowing between the membranes and/or adjusting the spacing between the membranes.

2. A method according to claim 1, wherein a liquid that is absorbtive with respect to solar radiation is arranged to flow over the inner membrane that is also absorbtive with respect to solar radiation, the outer membrane being at least substantially transparent to short wave solar radiation and relatively opaque to long wave heat radiation.

3. A method according to claim 2, wherein the liquid comprises water, Solvap Green, Eosin, soluble cutting oil, an aqueous solution of carbon black or a mixture of such liquids.

4. A method according to claim 1, wherein a gas is caused to flow between the inner and outer membranes, the outer membrane being at least substantially transparent to short wave solar radiation and relatively opaque to long wave heat radiation.

5. A method according to claim 4, wherein the inner membrane is absorbtive with respect to solar radiation.

6. A method according to claim 4, wherein the inner membrane is reflective with respect to solar radiation.

7. A method according to claim 4, 5 or 6, wherein the gas comprises air or smoke.

8. A method according to any one of the preceding claims, wherein the fluid is circulated between a heat store and the inter-membrane space by suitable pumping means.

9. A method according to claim 8, wherein the pumping means are reversible.

10. A method according to any one of the preceding claims, wherein the spacing between the membranes is adjusted by adjusting the gas pressure in the inter-membrane space.

11. A method of adjusting the properties of radiation reflector, transmission and/or absorption of a structural unit of double wall construction, having inner and outer membranes, substantially as herein described with reference to Figure 1 of the accompanying drawings.

12. A method of adjusting the properties of radiation reflection, transmission and/or absorption of a structural unit of double wall construction, having inner and outer membranes, substantially as herein described with reference to Figure 2 of the accompanying drawings.

13. A method of adjusting the properties of radiation reflection, transmission and/or absorption of a structural unit of double wall construction, having inner and outer membranes, substantially as herein described with reference to Figure 3 of the accompanying drawings.

14. A structural unit of double wall construction, comprising an inner membrane, an outer membrane, means for causing the flow of a fluid between the membranes, and means for adjusting the direction of flow and/or the nature

of the fluid and/or adjusting the spacing between the membranes.

15. A structural unit according to claim 14, wherein the outer membrane is at least substantially transparent to short wave solar radiation and relatively opaque to long wave heat radiation.

16. A structural unit according to claim 15, wherein the outer membrane comprises a film of transparent plastics material.

17. A structural unit according to claim 14, 15 or 16, wherein the inner membrane is absorbtive with respect to solar radiation.

18. A structural unit according to claim 17, wherein the inner membrane comprises a film of black or blackened plastics material.

19. A structural unit according to claim 14, 15 or 16, wherein the inner membrane is reflective with respect to solar radiaton.

20. A structural unit according to claim 19, wherein the inner membrane comprises a film of silvered plastics material.

21. A structural unit according to any one of claims 14 to 20, wherein the means for causing the flow of fluid between the membranes comprises suitable pumping means.

22. A structural unit according to claim 21, wherein the pumping means is reversible.

23. A structural unit according to any one of claims 14 to 22, further comprising a heat store in fluid communication with the inter-membrane space.

24. A structural unit according to claim 23, including means for causing circulation of the fluid between the heat store and the inter-membrane space.

25. A structural unit according to any one of claims 14 to 24, wherein the means for adjusting the spacing between the membranes comprises means for adjusting the gas pressure in the inter-membrane space.

26. A structural unit of double wall construction, substantially as herein described with reference to, and as shown in, Figure 1 of the accompanying drawings.

27. A structural unit of double wall construction, substantially as herein described with reference to, and as shown in, Figure 2 of the accompanying drawings.

28. A structural unit of double wall construction, substantially as herein described with reference to, and as shown in, Figure 3 of the accompanying drawings.

29. A building structure comprising at least one structual unit in accordance with any one of claims 14 to 28.

30. A building structure according to claim 29, wherein the structure is an air structure.

31. A building structure according to claim 29, wherein the structure is supported by a rigid frame.

32. A building structure according to claim 29, 30 or 31, wherein the building structure is used as a swimming pool cover.

33. A building structure substantially as herein described with reference to, and as shown in, Figure 1 of the accompanying drawings.

34. A building structure substantially as herein described with reference to, and as shown in, Figure 2 of the accompanying drawings.

35. A building structure substantially as herein described with reference to, and as shown in, Figure 3 of the accompanying drawings.

36. A method of regulating atmospheric conditions within a building structure in accordance with any one of claims 29 to 35, which method comprises adjusting the direction of flow and/or the nature of a fluid flowing between the membranes and/or adjusting the spacing between the membranes.

37. A method of regulating atmospheric conditions within a building structure, substantially as herein described with reference to Figure 1 of the accompanying drawings.

38. A method of regulating atmospheric conditions within a building structure, substantially as herein described with reference to Figure 2 of the accompanying drawings.

39. A method of regulating atmospheric conditions within a building structure, substantially as herein described with reference to Figure 3 of the accompanying drawings.

40. Any novel feature or novel combination of features disclosed herein.

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